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THE NEED FOR STANDARDIZATION PROCEDURES IN THE APPLICATION OF IONIZING RADIATION TO MEDICAL AND DENTAL PATIENTS [1]

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GENERAL

At the outset, I would like to make it clear that I have been requested by you to discuss the above subject, and this is not a subject of my own choosing. I would be presumptuous to think that I could do justice to this topic which would require me to be a specialist in many fields such as medicine, dentistry, radiology, x-ray technology, health physics, public health, industry, administration, education, law, and politics. I consider myself knowledgeable primarily in certain fields of health physics and can claim only superficial knowledge in the other areas indicated above. Therefore, the opinions expressed are my own and should be evaluated in combination with the views of specialists in other fields. These opinions do not necessarily represent those of the entire health physics profession, my employer or the national and international committees and associations to which I belong. I would like to consider what follows simply as the views of one person which must be added to and appropriately amalgamated with the views of many other experts before a well digested and scholarly proposal can be made available for appropriate action. It is my hope that this may serve as a useful beginning or preliminary discussion on a most important subject and that there will be a minimum of delay in combining these views with those of others in making this a working document which at an early date will provide guidance, direction and action on this most important subject.

Standardization, regulation and, if necessary, regimentation of procedures and/or techniques used in the application of ionizing radiation to medical and dental patients should be designed to provide the best possible needed diagnostic information with a minimum of absorbed dose (rad) and absorbed energy (gram-rad) to the patient, and the therapeutic treatment of the patient should be that which is considered best to provide a cure or amelioration of an undesirable condition in the patient with a minimum of damage and a minimum of dose from ionizing radiation to tissue not under treatment. Such standardization and regulation should:

(1) apply to routine procedures and operations
(2) apply to superior procedures and techniques
(3) avoid cookbook standards
(4) avoid mass production procedures
(5) not stifle research and the constant seeking after improvements
(6) not delay application of these improvements
(7) discourage useless or unscientific studies
(8) strike at the heart of the medical instrument problem by setting standards for the manufacture of medical and dental equipment
(9) require radiation exposure records
(10) standardize inspection programs
(11) set standards for new and

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improved educational programs (12) extend certification programs to all medical and paramedical personnel who authorize, apply or are responsible for the administration of ionizing radiation for human diagnosis or treatment.

1. STANDARDIZATION OF ROUTINE PROCEDURES AND OPERATIONS

In general, standardization should be limited primarily to those procedures and techniques or portions of them and uses of equipment that are considered to be rather routine in the application of ionizing radiation to patients. Usually, standardization should be limited to diagnostic applications, but in some cases it is applicable to therapeutic uses. It would not be practical at this point to attempt a listing of all medical procedures and techniques in accordance with those which are considered to be sufficiently routine that they can be standardized and perhaps come under some form of regulation and control. A few examples of such routine procedures, operations, techniques and use of equipment, however, might be useful even if they serve only to stimulate further discussion. They are as follow:

Amount and kind of x-ray filtration suitable for a given x-ray potential and for various classes of diagnostic and therapeutic use of x-rays

For example, a minimum kvp could be specified for routine dental radiography and the minimum amount of filtration could be specified for various voltage ranges at and above this minimum. Other examples might be to establish a minimum x-ray potential for a given type of x-ray equipment used in mass chest x-ray programs or to specify a maximum x-ray potential for use in the treatment of certain skin diseases, e.g., ringworm. As further illustration, regulations might specify whether the filtration can be removed and under what conditions it may be removed. Other such regulations and standards might be applied and enforced more efficiently at the factory where the x-ray equipment is manufactured, e.g., it might be required to incorporate permanently a minimum filtration in certain types of x-ray equipment.

Ratio of cross-sectional area of the primary x-ray beam at the end of the cone to the area of the x-ray film

I think that it would be practical to have a standard or regulation specifying an upper limit to this ratio for each or all types of diagnostic radiograms. I think that the specified ratio should be that of areas and not of diameters in order to encourage the use of diaphragms which have the same shape as that of the x-ray film. The Public Health surveys in 1964 indicated this ratio of areas was 3 to 6.8 or greater for 57% of dental x-ray exposures. (1) This represents a distressingly large amount of useless and unnecessary absorbed energy (gram-rad) delivered to the patient. Many of these standards could be improved in stages. For example, in this case, for dental radiograms the maximum ratio of the cross-sectional area of the beam at the end of the cone to the area of the dental film might be set at the present time at 2 with a six-month period of grace. Then, after a year or so of training and educational programs, this ratio might be reduced to 1 or 1½. The final regulation for all routine diagnostic exposures (dental and medical) might specify that all the edges of the flat plate area of the beam must show on the film. Also, there must be specified shapes and maximum areas of films for each size person for all the

more common or routine diagnoses. It is quickly recognized that none of these measures necessarily leads to the attainment of our goal, namely, to make the ratio of the flat plate area of the portion of the body under study to the flat plate area of the beam which strikes the x-ray film equal to unity. This ratio is always much more restrictive than the ratio of the cross-sectional area of the beam at the end of the cone to the area of the x-ray film. As equipment and techniques are improved and proven, the standards and regulations could be tightened to more nearly approximate our above-stated goal.

Film speed (Sensitivity)

I think there is great need to standardize film emulsions among the manufacturers so that one can quickly determine the sensitivity in terms of the published specifications printed on the box of films. On several occasions, the health physicist, Saul Harris (Department of Health, Education and Welfare, Public Health Service), has suggested that the present speed numbers or codes be replaced by inverse roentgens or rads. I think this suggestion has a great deal of merit but, if this is done, the values would have to be specified for a standard reference procedure; otherwise, the numbers would have little relationship to the skin dose and exit dose to the patient. One of the obvious advantages in this system of designation would be to direct the thinking of the physician to the dose received by the patient. An important area for standardization and regulation would be to restrict the sale and use of film of very low speed (sensitivity). There will be those who rightly claim that this may lead to a loss of resolution in the x-ray film shadows and that fine resolution is not possible with high-speed films. Therefore, the standard should be set so as not to deprive the medical profession of the resolution it needs and will use in a diagnosis but not to permit a lower-speed film than that which meets this requirement. The manufacturer of films and film intensifiers should be encouraged to seek the theoretical limit of film resolution for the higher-speed films.

X-ray film developing procedures

Standards and regulations could justifiably prohibit the use of outdated x-ray films. We hear stories at the present time of how legislation in one area may prevent the use of outdated films only to find them sold at a cut rate in other areas where there are no regulations against such use. Many times, the best radiographic results are not obtained because the films are improperly stored. Thus, standards could indicate the temperature and humidity of film storage facilities and the necessity of preventing contact with radioactive contamination and certain types of chemicals, e.g., SO_2, which would damage the films. In many cases, films which are developed in the darkrooms of dentists or practitioners do not provide the required medical information or they have necessitated overexposure to the patient because of poor darkroom procedures. Perhaps one of the most common of these poor procedures is the practice of overexposing the film and underdeveloping it in the darkroom. The regulations should discourage or prohibit this practice which is sure to overexpose the patient and certain to produce a radiogram of inferior quality. I do not believe that it is possible for the dentist to obtain best results in his search for caries in teeth if he makes a practice of purposely overexposing the film (and the patient) and then watching the film with the benefit of the safety light while it is in the developing solution and until an image begins to form and then slapping it into hypo.

Rather, he should give an exposure that is calculated and proven to give best results and develop the film in a lightproof darkroom using freshly prepared solutions (including rinsing solutions), a thermometer to control the temperature and a timer to determine the developing time. Public Health surveys have indicated that a large percent of the dentists do not even use a thermometer in their darkroom although the specifications for best results indicate the temperature control should be maintained within a few degrees. (2) The standards should specify careful temperature control, and under certain conditions should encourage the use of automatic developing equipment.

The cone used while making an x-ray exposure

Standards for cones, I think, should prohibit certain types of plastic cones. They should specify the minimum length of cones for certain types of medical exposures (e.g., dental) and should require the routine use of open-ended rather than closed cones for dental x-rays. The standards might specify that the primary beam be limited primarily by the use of diaphragms so that the primary beam does not actually strike the main portion of the cone. The atomic number of the cone and kind of surface material used in the cone perhaps should not be specified at the present time but, with study and experience, the best combination to limit the scattered photons as well as scattered electrons could be determined from a practical point of view and specified in future regulations.

Film holding

Standards definitely should outlaw the practice of the dentist holding the x-ray film in the patient's mouth. Perhaps it is too early to specify that the dentist not only use routinely the long, open-ended cone but also an attachment on the end of the cone to hold the film, collimate it so that the ratio of the cross-sectional area of the beam to the area of the film is 1 and provide a metal backing behind the film to prevent the radiation from passing into the body of the patient. I would hope, however, that this regulation could be arrived at very soon through several stages of progression and advancement of the dental profession toward our ideal of minimum unnecessary patient x-ray absorbed energy (gram-rad) with a maximum of medical diagnostic information.

Work load or milliampere seconds used in the exposure

It seems to me that the maximum milliampere seconds could be specified in the regulations for each routine type of diagnostic exposure of a patient. They could be given in table form for various sizes of patients, distances between x-ray target and film, film speed, etc.

Type of timer

Standards could be set for the type of timer manufactured and used routinely in various branches of the medical profession. The use of slow mechanical timers could be prohibited for certain kinds of operations or exposures where the dose rate to the film is high, the film speed is high, and it is not likely that other related parameters will be (or can be) properly adjusted without a fast timer. Further developments in phototiming may reduce the cost and make it practicable to require these be used, perhaps in series with a fast mechanical timer.

Mechanics of exposure

The standards for routine diagnostic exposures could specify how to center the beam to prevent cone cutting and to keep the x-ray machine, patient and film steady during the time of exposure, etc. Some of these standards or regulations should be applied at the manufacturing end.

Encourage discontinuation of certain types of routine use of x-rays

It seems to me that one of the most important standards or procedures would be to caution against or prohibit certain types of routine or periodic uses of medical x-rays. I have in mind routine dental surveys, routine mass chest x-ray programs, routine pelvimetries of pregnant women, etc. The Public Health Service stated in 1965, "Mass chest x-ray programs should not be given to all population groups but instead should be focused on groups within communities where the incidence of tuberculosis is known to be high." (3) I think this is a very commendable and valuable statement and provides the basis of an important standard in deciding where and how often mass chest x-ray survey programs should be conducted. There should be similar pressure from the U. S. Public Health Service to assure that when there is an indicated need and mass chest x-ray programs are conducted, only the best of techniques and good equipment properly tested and calibrated are used.

The American Dental Association stated in 1968, "Radiographic examinations should not be made periodically or be a standard part of every dental examination." (4) This, again, is an excellent standard but one that is often ignored by members of the dental profession and the public.

Since my testimony in support of bill H.R. 10790, 'Radiation Control for Health and Safety Act of 1968,' I have received over 300 letters from persons concerned about unnecessary radiation exposure. Many of them relate to exposures of pregnant women. I have received several letters from persons living in rather large communities where they claim that all the doctors in their area insist on a pelvimetry examination before they will accept a pregnancy case. I received letters from one individual who stated that his wife during pregnancy received a large number of fluoroscopic examinations while interns stood around presumably using this woman as a demonstration piece. Seven years after birth, her child died of a malignancy which, so far as I know, may or may not have developed as a consequence of this in uteral exposure. I am sure that this is a very exceptional case, but such things should never happen. The American College of Obstetricians and Gynecologists has stated, "The risk of radiation injury is real . . . and physicians should avoid the use of routine pelvimetry and routine radiologic examination of the abdomen throughout the prenatal era." (5) I think that this recommendation should be made an important standard for the minimization of radiation exposure during the most critical period in a human life. The International Commission on Radiological Protection also has made a statement to the effect that all unnecessary diagnostic exposure to women in the lower abdomen and pelvis should be avoided during the period when she may be pregnant. (6) They recommend that x-ray exposures of women in the childbearing age in the lower abdomen and pelvic region should be limited, where practicable, to the 10-day interval

following the onset of menstruation. A study by Schwarz has indicated a reduction in pelvimetries by more than a factor of 2 in the period 1950 to 1963 at the Sloane Hospital for Women has not resulted in an increase in neonatal mortality. (7) Of course, where exposure is necessary in relation to the immediate illness of the patient, it should be carried out without delay but with due regard (in the use of collimation, beam direction, shields, etc.) to the fact that exposures to the fetus may cause birth defects (microcephaly, mental retardation, microphthalmus, cataracts and skeletal abnormalities) and increase the probability of leukemia and other forms of cancer—especially of the central nervous system—in the early life of the child. (8, 9, 10, 11) A related problem, also, is that of minimizing exposures to the gonads of both males and females. At low dose rates (90 R/min) this is especially important in the case of the male because from the research of W. L. Russell it appears that there may be less repair of genetic damage from irradiation to the spermatogonia than there is from irradiation of the oocytes. (12) Any exposure to the ovaries of the female becomes a serious matter when we realize that it could result in a Mongoloid child (see Public Health report of Sigler) and that several studies have indicated diagnostic exposure to the woman prior to conception results in an increased incidence of leukemia among her children, and the mutation frequency for high dose rate exposure to oocytes is about twice that for such exposure to spermatogonia. (13, 14, 15)

Special exposure groups

I believe, for example, that special x-ray equipment should be designed, developed and put in routine use specifically with children in certain age groups. This could lead to the development of equipment better adapted to infants and young children and would simplify the x-ray procedure. Such equipment would make it easier to maintain the children in a quiet and unexcited condition during exposure and could lead to a considerable reduction in dose. It might even result in cost saving by reducing the need for adjustments and modifications of standard equipment and by reducing the number of overexposures and need for film retakes. It would encourage the referral of children to establishments having these better pediatric x-ray facilities.

Exposure records

Far more information should be obtained for exposure records than is available at present. Much of this information could be gotten as a routine before the examination begins. The routine information recorded by the x-ray technologist should include the social security number, dose estimates or dose readings, information about pregnancy, date of last menstruation, etc. The information should be gathered in a form best fitted for recording, evaluating and retrieval by computer systems. The subject is discussed later in more detail in this report.

2. STANDARDIZATION OF SUPERIOR PROCEDURES AND TECHNIQUES

Procedures and techniques which are standardized should be primarily those that are considered or proven to be superior to others under a great variety of circumstances. One could list as examples the use of certain minimum distances or long cones for specific types of radiograms. The greater distance provides better detailed medical information on the film while assuring less skin dose to the patient. On the other hand, greater distance from some points of view has the disadvantage of requiring a larger work load (mAs) for the x-ray machine and probably permits the processing of fewer patients per hour and may

shorten the useful life of the x-ray tube. However, I feel very strongly that the standards and regulations should be designed primarily to protect the patient and provide a maximum of useful medical information rather than to seek very minor savings in cost of equipment and its upkeep. A good example of superior techniques is that of following the proven recommended techniques and procedures in the use, storage, developing and reading of x-ray films. Most of these steps are time proven by many years of research and experience, and deviations from them may allow more of a mass production or a slight speeding up of procedures and lowering of cost, but, in general, recommended techniques should be followed very closely in obtaining the maximum medical information with the lowest possible patient dose. Many of the procedures such as the use of proper filters to cut out some of the useless soft x-rays and the use of higher voltage well above the photoelectric region for soft tissue, but not too far into the Compton region where the contrast becomes poor due to the relative independence of the attenuation coefficient on the atomic number of the material are examples of standards which should be set. They are based on a firm theoretical consideration, an understanding of the problem and many years of practical experience. Another example of a principle that has proven to be reliable is that for the usual chest x-ray and/or for other types of radiographic examinations where dynamic information is not required, less dose is delivered to the patient, and more useful and pertinent medical information is provided from a radiogram than from a simple fluoroscopic examination, i.e., without the use of an image intensifier, storage camera tube, videotape, etc. I believe that the standards should be so set as to prohibit what I consider the improper use of a fluoroscope as a substitute for the usual chest radiogram. To explain what I have in mind, I might mention a letter I received on October 18, 1967, from a man living in Pennsylvania which states in part, "I receive a fluoroscopy as part of my biannual physical examination for my private pilot's license. . . I am not sure if a fluoroscope should be used periodically as a routine part of an examination for a third-class airman medical certificate. Is this exam, consisting of about five pictures from thighs to head, each about one second long, more of a risk than is justified? Would you recommend a fluoroscopy as a routine part of a regular, periodic examination?" This private practitioner is fluoroscoping this young man twice a year and, of course, does not avail himself of any of the modern equipment designed to reduce the fluoroscopic exposure of the patient. I would estimate this young man is receiving several hundred times the dose necessary for his biannual physical examinations for the private pilot's license. I believe the regulations for the licensing of an aircraft pilot as well as the regulations for the use of x-rays should be made sufficiently clear and specific that they prohibit such practice as brought to light by this letter. As examples of equipment or procedures that have not been proven to be superior, I might mention that although the use of buckys and film intensifiers are known to improve radiographic results, no one type is proven to be superior for all applications and procedures. In these cases, the standards could provide guidance and direction to indicate for which procedures certain types of equipment appear to be preferable, but they should not necessarily be so restrictive as to permit the use of only one particular type of bucky or intensifier or require their use for all types of examinations.

3. AVOID COOKBOOK STANDARDS

Whereas, as indicated above, sufficient detail should be given to provide guidance of when a bucky should be used and what type is

preferable for certain types of examinations, care should be taken not to provide too much detailed information which would be followed by the medical or paramedical man in parrot fashion. Steps in the procedures which are unimportant or are not unique in providing a better radiogram with less exposure to the patient should not be recorded. Certain steps and procedures could be given, for example, on how to hold the young patient or use restraining devices for an x-ray examination, but to set up a standard procedure giving details on how to hold a child would not leave enough to the imagination and ingenuity of the x-ray technologist. I would consider it especially important to avoid too much detail in the standards as they relate to therapy. Here, for example, I think the regulations should limit the potential of the x-rays used for skin treatments, e.g., ringworm, but should make no specifications on the kvp, filtration, area of the field, dose rate, fractionation of the dose, portals of entry of the beam, etc., in the treatment of a malignancy. (16, 17) The regulations in this case must not even limit the primary dose to the volume of tissue which is thought to be malignant because there may be good reason for irradiating certain of the adjacent tissue. A good example of what I consider a mistake in the past in providing too much cookbook information was that instruction which indicated one should use a higher x-ray potential in the case of Negro patients. Apparently, in many cases, this instruction was misinterpreted to mean higher exposure, thus further amplifying this mistake. For example, I have a letter from an x-ray technologist dated November 7, 1967, which states, "There are technicians who are trained to irradiate Negroes with ¼ to ½ extra dosage because 'their bones are harder,' 'their bones are denser,' 'their skin is darker,' 'their skin is firmer.' We took a survey asking about 90 technicians if they give extra dosage to Negroes and why. About 80% said they did and gave the above reasons. Many physicians support them (have so trained them) and no one except a few of us have ever questioned the theory . . . so in a very great majority of x-ray examinations today in the United States, Negroes as a group are receiving anywhere from ¼ to ½ more radiation than whites." We all agree that higher x-ray potential and higher dose to the patient is required if he is heavier, thicker and if of larger build. Undoubtedly, this on the average applies to the Negro who is inclined to be larger and more robust. It is unfortunate, however, if a large number of technicians and technologists are greatly influenced in their procedures by this very crude guide or rule of thumb rather than make their voltage, current and distance settings on the basis of the physical characteristics of each individual patient. I have discussed this matter with a number of radiologists and x-ray technologists and am led to believe that when a person comes in the room to be x-rayed, it would be far better for the radiologist or x-ray technologist to be "color-blind" and completely oblivious to any differences in color or shades of the skin.

4. AVOID MASS PRODUCTION PROCEDURES

As indicated in the above discussions, some of the x-ray medical procedures seem to be designed more for mass production and to hurriedly herd large numbers of patients by the portable x-ray equipment or through the x-ray department than they are designed to provide needed individual care. This sometimes has led to shortcuts in the operation, sloppy techniques that guarantee a quality of x-ray diagnosis that is non-professional (e.g., the poor darkroom techniques used by many dentists) and the adoption of routine procedures including x-ray examinations which, in many cases, are not needed and had better be dispensed with. As an example, I would

consider unwarranted an assembly-line procedure which leads a hospital or group of doctors to request that each pregnant woman who expects to have a baby delivered under their care have a pelvimetry. I realize, of course, that in some cases assembly-line techniques may be required, for example, in the use of portable x-ray equipment when mass chest x-rays are taken in areas with a high incidence of tuberculosis. In these cases, however, the use of rigid standards becomes even more essential because large numbers of young people are involved. Some of the photofluorometric (or photoradiographic) equipment now used gives a skin dose to the child which may be as much as five times (and an absorbed energy as much as 10 times) that delivered by other similar equipment. It seems to me rather urgent that standards be set which will require the use of equipment which delivers a dose approaching the minimum while at the same time obtaining completely satisfactory medical information for which the survey is designed. Many factors can affect this skin dose and energy absorption by the patient. Some of the obvious ones would be the voltage used, the distance between the child and the x-ray tube, the filtration, diaphragms which should limit the beam to the area under study and in no case greater than the area of the fluorescent screen, a clean fluorescent screen of high quality, photographic film with a high efficiency for the light output of the fluorescent screen, a photographic film with the highest possible speed which will provide the necessary medical information and a high-quality photographic lense with a very low f number (certainly, no higher than 1.2).

5. DON'T STIFLE RESEARCH

One of the more important medical-public relations problems has always been how to give the patient the best of individual medical care while at the same time seeking every opportunity for research and improvement of equipment and techniques used. Most patients do not wish to be guinea pigs, and we are always quick to agree that research should be avoided if it in any way interferes with the health and recovery of the patient. This means, of course, that it is necessary sometimes to walk a very narrow chalk line between what is known to be a proven treatment considered most likely to benefit the patient and what may lead to unknown consequences which may or may not be harmful to the patient. I believe the standards, regulations and procedures should be so set that they encourage a constant improvement as illustrated in the discussion above of steps that might be taken in reducing the ratio of the cross-sectional area of the beam of the area of the film. Significant deviations from standard procedures and explorations in the use of new equipment, drugs and techniques, however, I believe should be limited primarily to those who have special competence and certification to carry out research that can be expected to be productive and will assure the maintenance at all times of the highest of ethical and professional standards. Because of the cost of supportive equipment and the necessity of bringing together a critical mass of brainpower in order to conduct the most promising research, it will probably be necessary to center most of the advanced research and the application of the most atypical medical procedures in research institutions where, for the most part, diagnosis and treatment is limited to incurable diseases and/or terminal cases. I would not wish to under-emphasize, however, the importance of making the standards such that the individual dentist or radiologist would be encouraged to constantly improve his techniques, always with the goal of maximizing the ratio of the medical benefits to the patient to the risks from radiation exposure.

6. DON'T DELAY APPLICATION OF IMPROVEMENTS

One of the principal reasons for avoiding unnecessary standardization, regulation or regimentation in the application of ionizing radiation to medical and dental patients is the risk of unnecessarily delaying the application of improvements and new developments brought about by research. Such delay can be prevented to a considerable extent by avoiding cookbook standards, by carefully wording the standards and procedures in such a way as to encourage the constant seeking for improvements in techniques and equipment. I think to a large extent the standards should anticipate improvements and should lead the dentist, radiologist and technician in the use of better principles and techniques that are expected to provide better x-ray diagnosis with less exposure to the patient. For example, at present the NCRP recommendation for dental protection of the patient states that the useful beam shall be restricted to a diameter of not more than three inches at the end of the cone. This is given in spite of the fact that for some time the American Dental Association itself is more conservative and sets this limit at 2.75 inches. At 2.75 inches the ratio of the beam area to the film area is 1.6% less than it is at three inches. Since the Public Health survey in 1964 indicated that 43,8% of the dentists were already operating with a beam diameter of less than 2.75 inches, it would seem reasonable that this should be set as the present standard with every possible encouragement to operate at a smaller diameter and use film-holding and collimating devices on the end of the cone such that the ratio of beam cross-sectional area to film area becomes 1 or less. (18) Standardization should never stoop to or countenance the worst of procedures in current use by the profession any more than a school classroom should cater to the laziest and dumbest student in the class. It would, of course, be improper to pass legislation that would suddenly outlaw all x-ray equipment for which the beam diameter at the end of the cone is greater than 2.75 inches, but the laws could set a date at which this standard must be met, and they could anticipate a further date at which the ratio of beam area to film area would become 1 or less. The present standards could require the use of image intensifiers in medical fluoroscopy, but they should not, at this stage, specify the type of cassette and intensifier or rule out the possibility of the radiologist or medical facility selecting the camera tube most suitable or considered to be most desirable for its own application. The standards should encourage the development of equipment such as the image orthicon, vidicon and the secondary electron conducting camera tube. Our goal should be to encourage the continued improvement and early adoption of these devices and other principles, many of which have not yet advanced beyond the theoretical stage, such that in time many of us believe medical exposure to ionizing radiation can be made almost negligible.

7. DISCOURAGE USELESS OR UNSCIENTIFIC STUDIES

To illustrate what I have in mind here, I might mention the fact that about a year ago I was contacted concerning a test of various types of toothpaste that was to be conducted in one of our small cities. The children were to each be given a year's supply of toothpaste, the kind to be designated only by numbers. During the course of the study, the children were to receive eight x-ray examinations to see what effect, if any, the various brands of toothpaste were to have on the development of caries. From what I could learn about the study, it appeared that it had been planned prior to the assurance that the x-ray equipment used had been properly checked and

calibrated in order to assure giving a minimum of exposure to the children. Furthermore, it appeared that this was an unnecessarily large amount of x-ray exposure which would be given to many children where such diagnoses were completely unnecessary for their own benefit. Finally, I questioned whether all phases of the study were being conducted in a scientific manner such that the data would be of statistical significance and be published in the open scientific literature and whether they would be of general value either for the improvement in toothpaste or for the prevention of caries in children's teeth. The excuse was given that the dental x-ray films would be made available to the children's dentists, and thus the program had been justified on medical grounds. If similar studies were carried out in order to test each new brand of toothpaste as an additional ingredient is added, such surveys could mushroom to where our children would be serving as little more than guinea pigs for the testing of industrial products. My attention was called recently to a similar but perhaps non-medical use of x-rays where the use might provide interesting and useful scientific information and lead to important further studies. (19) However, my first reaction has been to discourage such a program. I have in mind the publication and recommendation by a professor at a school of music who proposes using the x-ray machine as an adjunct in music departments. This particular study is in relation to a cooperative program of a music professor and a radiologist and makes reference to similar studies in several universities. The program consists of taking fluoroscopic pictures of the head, throat and chest of music students as they play various mouthpiece musical instruments or strike various notes with their vocal chords. Apparently, this study was carried out earlier using x-ray movie equipment, and they are now using x-ray videotape. From the data I have in hand, it is difficult to make an accurate estimate of the dose delivered to the central nervous system, thyroid, red bone marrow and other organs of the body of these young students, but it does appear high enough to urge that such programs be discontinued. It would seem that although this might be a scientific or pseudo-scientific use of x-rays, there must be other less risky ways by which music departments can obtain the same information. I feel, also, that standards in reference to the use of x-rays in medicine and dentistry should be broadened to include all uses of x-ray on man, and they should offer proper control or prohibit certain types of research which may involve such planned exposures to music students.

8. STANDARDS IN THE MANUFACTURE OF MEDICAL AND DENTAL X-RAY EQUIPMENT

Next to education, training and motivation of all members of the medical and paramedical profession, this may be the most important area for effective standardization. For example, if the dentist is able to purchase films only of a minimum speed (sensitivity) and, if the hospital can purchase and install only x-ray equipment meeting certain basic standards, a great deal of the problem can be corrected at the source. If a standard states that only the long, open-ended cone may be used with dental x-ray procedures, why not prohibit the sale, shipment or transfer of equipment other than that with the permanently fixed, long, open-ended cone? Some might complain that there are dental x-ray procedures where this long, open-ended cone would be awkward in use or inapplicable. I am confident, however, that other ways can be found to carry out such procedures using machines with a long cone. Similarly, if it is decided to recommend a minimum voltage for dental radiography, why provide machines that can be operated below this voltage. Many surveys have indicated that

large and unnece[illegible] skin doses are delivered to the patient [illegible]ause filters have been removed from the x-ray machine. This suggests the construction of a machine with a fixed minimum or inherent filtration and with automatic filter changers which operate as the voltage of the machine is changed. If the standards prevented the manufacture, sale and transportation of equipment which failed to meet what appear to be reasonable minimum requirements for filters, cones, voltage and current meters on the x-ray machine, etc., again much of the problem could be corrected at the level of the manufacturer.

I would like also to mention a related problem, namely, the unauthorized transfer or donation of x-ray equipment. I know of cases where old and outdated x-ray equipment has been donated to high school and college science departments. This has led to its use by untrained and uninformed individuals and to unnecessarily high exposures to students. Obviously, the regulations should control and/or prevent such transfers.

9. REQUIRE EXPOSURE RECORDS

Over a decade ago, I was of the opinion that it would be inadvisable to attempt to keep medical exposure records on individuals. In fact, I was at that time on an international committee and concurred in its recommendation to this effect. (20) However, during the intervening years, I have changed my views for four reasons:

greater need with the rapid increase in use of medical x-rays and other sources of exposure to ionizing radiation

improved instruments for measuring absorbed dose

more evidence of a linear dose-effect relationship at very low doses

the availability of computer systems for the recording, evaluating and retrieval of information.

The need for such information is emphasized by the 1964 U. S. Public Health Service reports which indicated that in that year there were 105 million radiographic examinations, 53.6 million dental examinations, 10.7 million fluoroscopic examinations, and 3.4 million therapeutic examinations in the United States. (1) Reports of recent date have indicated the past doubling period has been about 13 years and that this period may have decreased recently due to the extensive use of Medicare. (21) There have been marked improvements in dosimetry during the past few years, and many of the large nuclear energy organizations are converting from film dosimetry to solid state dosimetry. Thermoluminescent and photoluminescent meters are available which provide a sensitivity, accuracy, and usefulness which is equal to or greater than that for film meters in terms of dose response, energy independence, reliability in preserving the dose information until retrieved, accuracy, and ease with which this information can be retrieved and/or permanently stored by the technician and/or automatic reading devices and extremely small sizes of meters so that they would not interfere if placed in the diagnostic and therapeutic primary beam. These are only a few of the instrument developments that would greatly simplify and make more meaningful medical exposure records. This past year a number of scientific reports have been added to the list which add strength and credibility to the assumption that certain types of somatic damage such as leukemic incidence and thyroid cancer relate linearly to the energy absorbed in the critical tissue (gram-rad dose). (22, 23, 24) Recent genetic studies at Oak Ridge with mice indicate that, although there may be a reduction by a factor of six in genetic mutations per roentgen at dose rates less than 1

R/min, there seems to be no further reduction at lesser doses. This dose rate effect is a complicating factor, but it merely means that one would need to keep a record of the dose rate as well as other parameters such as the cross-sectional area of the field, the energy of the radiation, the portion of the body in the direct beam, the reading of the solid state dosimeter placed on the film, etc. It even seems rather promising that certain types of dosimeters could be built in and made a part of the film and that the reading of a meter can be carried out by an automatic reading device. I think that our system of standardization should provide that these records be kept in such a way that they can be sent to central record keeping facilities and placed on a computer. With such a system, the doctor in the future merely need press certain specified buttons on his telephone or instrument panel, and he would have typed out immediately before him the complete exposure history of the patient.

10. STANDARDIZED INSPECTION PROGRAMS

I doubt if any federal or state system of enforcement of standards can be better than the inspection program which sees that these standards are properly complied with. This means that certain standards must be met in the federal and state inspection programs which carry out these inspections and enforce these standards. The inspection programs must be manned by highly competent inspectors who have proper experience, training, education, and certification. As with a doctor or x-ray technologist, they must avoid making the job no more than a cookbook procedure, but they can simplify and increase efficiency of their surveys by developing certain standard procedures which they follow in each inspection of the medical equipment, facilities and techniques. These inspectors or health physicists, however, must be more than technicians because they must have sufficient scientific training and understanding of the problems of dosimetry, the operation of x-ray equipment, use and interpretation of dosimeter readings to carry out a thorough and meaningful inspection under a great variety of circumstances.

11. IMPROVED EDUCATIONAL PROGRAMS

I consider this the most important of all these items discussed. Unless the program of standardization begins in the medical schools and universities and unless it develops the proper motivation for radiation protection and high quality x-ray information at all levels in the medical and paramedical professions, these other efforts can be more or less a waste of time. I do not believe that the education and training in the use of medical and dental x-rays should be stereotyped or identical in each of the educational systems, but there must be certain minimum standards which are met. I believe, also, that it is important that more basic knowledge and understanding of x-ray physics, health physics and radiation biology should be provided a student so he can build on and add to this information and be able to reason for himself the meaning and purpose of various procedures that he must use for improved medical practice with a minimum of exposure to the patient. I believe that the medical and paramedical student should be made less of a parrot and more of a scientist. He should be encouraged to continue building a scientific foundation throughout his professional career by reading, research and recertification from time to time so that he can better adjust and adapt himself to new medical procedures and techniques. He should have a thorough understanding and appreciation of the importance of striving for the best possible radiograms with a minimum of dose

to the patient. This is what we mean by proper motivation.

12. EXTEND CERTIFICATION PROGRAMS

I believe that all medical and paramedical personnel who prescribe, administer or operate x-ray equipment which exposes the patient should be educated, trained, and certified in the use of such equipment. They should have as much education as possible in radiation physics, x-rays; radiation protection (health physics) and radiation biology. I believe that it is desirable that sample state legislation be made available as soon as possible relating to the standards to be met in these certification programs so that there will be suitable uniformity in the certification received through the various state programs. I believe that the certification of x-ray technologists should not only be as good as but better than the present certification provided by the ARRT which I believe is under the joint sponsorship of the American College of Radiology and the American Society of Radiologic Technologists. I believe the standards for this program should be set in joint cooperation with a number of groups, but especially with the x-ray technologists themselves, and with the help of their organizations, the American Society of Radiologic Technologists and the American Radiographic Technologists. These efforts must be in cooperation with the American College of Radiology and the American Medical Association, but valuable assistance can and should be obtained from health physicists, medical, and hospital physicists and, especially from those who have had the experience in the present training programs. I believe there should be several grades of training for the x-ray technologist and x-ray technician; for example, the training of dental x-ray technicians need not be nearly as comprehensive as the training of medical x-ray technologists. I believe that some of the x-ray technologists must have training and certification for therapy as well as diagnostic work, and an increasing number must have training in the use of radioisotopes. I believe that it goes without saying that the primary responsibility for medical exposure to the patient rests with the dentist, doctor or radiologist. But, in practice, we will always find that a great deal of this responsibility must be and usually is passed on to the paramedical personnel since very often, and rightly so, the busy radiologist or dentist is present only in absentia during the making of x-ray exposures. (25, 26) The doctor is involved and responsible because he prescribes the x-ray exposure and must have a full appreciation of both the risks and the benefits to be expected.

Finally, it cannot be emphasized too strongly that our primary goal of maximizing the ratio of the benefits from the use of ionizing radiation to its harmful effects cannot be accomplished solely through education, training, certification and proper motivation in the universities and medical schools. The system that is established must require a program of continuing education, training, refresher courses and the requirement for recertification from time to time of the radiologist, practitioner, dentist, chiropractor, x-ray technologist, and dental x-ray technician. I believe the public can only be reassured that the doctor, dentist and x-ray technologist that provides an x-ray examination is qualified, up-to-date, and using the best of equipment and techniques designed to provide the needed medical information with a minimum of exposure if he can see posted near the x-ray machine a certificate indicating appropriate certification with proper dating to assure the certification is maintained current. He must see also a certificate indicating recent inspection of the x-ray equipment. Finally, but not least, an important part of the education and training program is that of the public. The public must be given a

better understanding and appreciation of the problem. The public must be a party to the standardization procedures. It must have a greater measure of understanding and appreciation for both the benefits and risks from the use of ionizing radiation and strongly support this standardization program and be made to realize that it is intended to provide assurance that he, the public, receives the best of medical care.

REFERENCES

1. Gitlin J. N. and P. S. Lawrence. **Population Exposure to X-Rays. U.S. 1964,** Public Health Service Publication No. 1519, U. S. Government Printing Office. Washington, D.C.

2. Chadwick D. R. "USPHS Division of Radiological Health Program in X-Ray Protection." presented at the Public Health Conference on the [Use of X-Rays in Medicine and Industry.] University of Miami, Coral Gables, Florida, April 13-15, 1966.

3. U. S. Department of Health, Education and Welfare, Public Health Service Publication No. 1196. **What About Radiation? Mass Chest X-Ray Programs** (February 1965).

4. American Dental Association Council on Dental Materials and Devices and Council on Dental Research. "Radiation Hygiene and Practice in Dentistry. IV." **J. AMER DENT ASS,** Vol. 76, p. 363 (February 1968).

5. "American College of Obstetricians and Gynecologists Adopts New X-Ray Policy." **AMER. COL. RADIOL. BUL.,** Vol. 20, No. 9 (September 1964).

6. International Commission on Radiological Protection Publication 6 **Recommendations of the International Commission on Radiological Protection,** Pergamon Press, New York (1964).

7. Schwarz, G. S. "Radiation hazards to the human fetus in present-day society." **BUL. N. Y. ACAD. MED.,** Vol. 44, No. 4, p. 388 (April 1968).

8. Dekaban, A. S. "Abnormalities in children exposed to x-radiation during various stages of gestation: Tentative timetable of radiation injury to the human fetus, Part I." **J. NUCL. MED.,** Vol. 9, p. 471 (1968).

9. Kusano, N. "Review of the late clinical effects of the atomic bomb in Hiroshima and Nagasaki." **LIV. COND. HEALTH,** Vol. 1, p. 256 (1959).

10. "Pre-Natal X-Ray and Childhood Neoplasia. "Division of Biology and Medicine, AEC, TID-12373 (April 1, 1961).

11. MacMahon, B. "X-Ray exposure and malignancy." **JAMA,** Vol. 183, p. 721 (1963).

12. Russell, W. L. "Studies in mammalian radiation genetics. "**NUCLEONICS,** Vol. 23, No. 1, p. 53 (January 1965).

13. "Father's Radar Exposure Related to Mongolism?" **PUBLIC HEALTH REPORTS,** Vol. 81, No. 3, p. 225 (March 1966).

14. Stewart A. et al. "A survey of childhood malignancies." **BRIT. MED. J. ASSOC.,** Vol. 183, p. 721 (1963).

15. Graham S. et al. "Preconception, intrauterine, and postnatal irradiation as related to leukemia." **Epidemiological Approaches to the Study of Cancer and Other Chronic Diseases,** NCI Monograph 19 (January 1966).

16. "Radiation injury hazard in ringworm therapy." **MEDICAL WORLD,** p. 80 (December 10, 1965).

17. Albert, R. E. "Follow-up study of patients treated by x-rays for tinea capitis," **AMER. J. PUBLIC HEALTH,** Vol. 56, p. 2114 (December 1966).

18. Winkler, K. G. "Influence of rectangular collimation and intraoral shielding on radiation dose in dental radiography." **J. AMER DENT ASS,** Vol. 77, No. 1 (July 1968).

19. "Transparent man with a horn," **THE NORTH TEXAN,** Vol. 19, No. 5, p. 7, published by North Texas State University (October 1968).

20. "Exposure of Man to Ionizing Radiation Arising from Medical Procedures," a report of the International Commission on Radiological Protection and the International Commission on Radiological Units and Measurements submitted to the **United Nations Scientific Committee on the Effects of Atomic Radiation (1957).**

21. National Advisory Committee on Radiation (R. H. Morgan, chairman). **Protecting and Improving Health Through the Radiological Sciences,** U. S. Department of Health, Education and Welfare, Public Health Service (April 1966).

22. Doll R. and P. G. Smith. "The long-term effects of x-irradiation in patients treated for metropathia hacmorrhagica." **BRIT. J. RADIOL.,** Vol. 41, p. 362 (May 1968).

23. Hempelmann, L. H. "Risk of thyroid neoplasms after irradiation in childhood." **SCIENCE,** Vol. 160, p. 159 (April 12, 1968).

24. Dolphin, G.W. "The risk of thyroid cancers following irradiation." **HEALTH PHYSICS** Vol. 15, p. 219 (1968).

25. Tolan, J. H. "Some thoughts on the question of responsibility for radiation protection in diagnostic radiology," **HEALTH PHYSICS** (March 1969).

26. Schaeffien, J. W. "Licensing of radiological technologists: A summary of the current controversy, **HEALTH PHYSICS** (March 1969).

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Karl Ziegler Morgan was born in Kannapolis, North Carolina, in 1907. He received the A. B. degree in 1929 and the M. A. degree in 1930 from the University of North Carolina. He worked with the Westinghouse Electric Corporation in 1931 and received the Ph.D. degree in physics from Duke University in 1934. From 1934 to 1943 he was Chairman of the Physics Department of Lenoir Rhyne College, and during this period he did research work in cooperation with Duke University in the field of cosmic ray showers, the meson lifetime, etc. This led to a number of cosmic ray expeditions, among which were measurements in Linville Caverns, on the top of Mt. Mitchell, on Beech Mountain (all in North Carolina) and on Mt. Evans near Denver, Colorado.

He became a member of the Metallurgical Laboratory staff at the University of Chicago in the spring of 1943. Here he was one of a group of six persons who developed and established the new science known as health physics, which today employs thousands of persons in countries throughout the world.

A health physicist is a person engaged in the study of problems and practices of providing radiation protection; he is concerned with an understanding of the mechanisms of radiation damage, with the development and implementation of methods and procedures necessary to evaluate radiation hazards and with providing protection to man and his environment from unwarranted radiation exposure. Health physicists have become a vital part of many organizations - private research laboratories, government laboratories, universities, hospitals, military service, space programs, reactor programs, state and Federal public health organizations, international organizations such as the International Atomic Energy Agency and the International Commission on Radiological Protection, etc.

During the fall of 1943, Morgan transferred to the Oak Ridge National Laboratory where at present he is Director of the Health Physics Division which employs 250 persons engaged in research, engineering, and applied problems. In 1956 he was the first president of the Health Physics Society, an organization which now has over 3,300 members. At present, he is president of the International Radiation Protection Association consisting of 16 affiliated societies with over 6,000 members in some 50 countries. He is a member of the Board of the Society, a member of the American Board of Health Physics which certifies health physicists in the United States, and is Editor of the journal HEALTH PHYSICS. He is a member of a number of committees dealing with problems of radiation protection such as the National Research Council Committee on Shipment of Radioactive Substances, the Main Commission of the International Commission on Radiological Protection, the National Academy of Sciences' Civil Defense Committee, the Advisory Committee on

Radiation Bio-Effects of the United States Public Health Service, and the Board of the National Council on Radiation Protection. He is chairman of the national and international committees of ICRP and NCRP dealing with maximum permissible internal dose of radioisotopes. He has published approximately 150 papers dealing with subjects of cosmic rays, radiation protection, instrumentation, and general health physics.

One of the current problems of interest is the study and development of suitable methods of radioactive waste disposal that can be applied when atomic energy reactors are widely used as a source of electrical power. The Health Physics Division, of which he has charge, has recently made a number of important engineering advances in the study of disposal of radioactive waste with respect to both liquid and gaseous contaminants. This same Division has led the way in the training of health physicists who, in turn, have established health physics programs in many universities, hospitals, and industrial laboratories. The Oak Ridge National Laboratory Health Physics Division has developed the first instruments with which quantitative measurements of concurrent dose of gamma rays and of fast neutrons can be made and it is now in the process of measuring many physics constants useful in estimating radiation damage such as the electron volts per ion pair, stopping power, drift velocity, attachment coefficient, scattering of ionizing radiation as it passes through matter, electron infinity, etc. The principal objective of the health physics programs, under the direction of Morgan, is to develop an understanding of the basic mechanisms of radiation damage and, eventually, to develop a coherent theory of radiation damage in order to obviate the necessity of risky extrapolations in the establishment of levels of maximum permissible exposure to ionizing radiation.

Other important programs in the Health Physics Division include radiation ecology, health physics technology, internal dose and radiation dosimetry. In this latter program one of the projects is that of determining the dose received by the individual survivors of the atomic bombings in Hiroshima and Nagasaki, Japan.

In 1953 the National Council on Radiation Protection Subcommittee on Internal Dose, of which Morgan is Chairman, released the first internal dose report, listing the maximum permissible body burden and maximum permissible concentration of some 70 radionuclides. The following year another committee of which he is chairman released for publication by the International Commission on Radiological Protection a report entitled "Permissible Dose for Internal Radiation" extending these calculations to 240 radionuclides. Both the above internal dose reports are in process of revision (see "Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure," NCRP-NBS Handbook 69 (June 5, 1959), Report of Committee II on "Permissible Dose for Internal Radiation," ICRP Publication 2 (1959), and ICRP Publication 6 (Pergamon Press, April 1964).

In August, 1962, the Royal Academy of Science of Sweden awarded its first gold medals for meritorious work in the field of radiation protection. This award was given jointly to W. Binks, Director of Radiological Protection Service, Surrey, England, and to K. Z. Morgan for their contributions to the field of radiation protection during the past 10-year period.

In May, 1964, Morgan received the 1964 Distinguished Alumni Award which was presented to him by the Lenoir Rhyne Alumni Association, Lenoir Rhyne College, Hickory, North Carolina, in recognition of outstanding service in his field of endeavor. In 1957 at Berea College, he was elected by the National Executive Council to honorary membership in Sigma Pi Sigma, the physics honor society. He was awarded an honorary Doctor of Science degree from Lenoir Rhyne College in May, 1967, in recognition of his distinguished career and contribution as a health physicist whose achievements in the field of cosmic ray research and radiation protection are highly meritorious and internationally acclaimed.

Morgan is a member of the American Public Health Association, the American Association for the Advancement of Science, the American Industrial Hygiene Association, the Research Society of America, the Radiation Research Society, the Tennessee Academy of Science, the Society of Nuclear Medicine, the American Association of Physicists in Medicine, an Associate Fellow of the American College of Radiology, a Fellow of the American Physical Society and of the American Nuclear Society, and an Affiliate of the Royal Society of Medicine.

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U.S. Department of Health, Education and Welfare, Consumer Protection and Environmental Health Service, Environmental Control Administration, Bureau of Radiological Health (1969)

ABSTRACT: It is recognized and emphasized that ionizing radiation is one of the most valuable and essential diagnostic tools of medicine. Every effort should be made to enhance the beneficial uses of this source of energy while minimizing its harmful effects. It is estimated that more than 90% of man-made exposure to ionizing radiation arises for medical diagnosis and that a large fraction of this represents unnecessary exposure. This perhaps is what we could expect when we realize that a large fraction of those in the medical profession who authorize, supervise and administer these x-ray examinations do not have the education, training and certification in its use. As a consequence, much of the equipment and many of the

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